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AGRICULTURAL RESEARCH IN THE WAR AND AFTER

IN a recent address (1) to the Convention of the Association of the American Land-grant Colleges and Universities Dr. E. C. Auchter (2) discussed what agricultural and related research work had done for the United States in the past, what it was accomplishing at present and what it might be expected to accomplish in the future. We propose here to mention some of the major issues regarding agricultural research to which Dr. Auchter referred, especially as they concern not only the United States but also other countries in the world.

At the outset Dr. Auchter paid a tribute to the manner in which agricultural research workers in the United States have faced the tremendous challenge made by this war. "That they are meeting it successfully," he said, "is witnessed by the result—an unprecedented agricultural production, the development and utilization of new foods, drugs, fibres and strategic materials of many kinds: improved methods of distribution, packing and processing of agricultural products, and increased knowledge of requirements for foods and other products needed in everyday living. These results have been made possible by utilising the materials and knowledge accumulated through scientific research, as well as by effective organization for developing new knowledge to meet emergency needs. Scientists in all fields related to agriculture are playing an important part in this work and will play an even more important one in the future. Just as great a challenge awaits research in the post-war world as it faces now. . ."

In so far as the past was concerned Dr. Auchter said that agricultural research had increased agricultural efficiency, step by step, and year by year, and that it had in turn played a large part in enabling the United States to build and operate greater industries. "It would be absurd and untrue, of course", he added, "to say that only research directly connected with agriculture has made our industrial development possible. Progress is based on the exchange of knowledge developed in many fields. But the fact remains that the research of the land-grant colleges, the

(1) *Science*, Vol. 99, Nos. 2566 & 2567, 1944.

(2) Administrator of Agricultural Research, U.S. D.A.

State experiment stations, the United States Department of Agriculture and our universities and other institutions dealing more or less directly with agricultural and related problems has not only paralleled but to a large extent stimulated the great progress in agricultural efficiency made in this country since 1860—progress that helped make our industrial civilization possible. And our agricultural institutions have not been content with doing a vast amount of productive research; they have carried the results directly to the farmer and have shown him how to apply them, thereby cutting down the time that would otherwise be required for the adoption of new practices."

Referring to the agricultural situation after the first world war Dr. Auchter recalled that there was a period of pessimism about research, especially during the depression, when there were huge surpluses of some farm products. Somehow there was a feeling that research was at least partly to blame for those surpluses which in actual fact were not surpluses at all in relation to world needs, since at least half of the world's people are not properly fed. "The true situation was that scientific progress was far ahead, temporarily at least, of economic and social progress. We knew how to produce, but not how to get the products to the people who needed them. We did not know how to maintain what the economists call "effective demand". Then the present war came .... which automatically created "effective demand", in terms of astronomical figures .... That demand could never have been met had it not been for the advances farmers had made in production on a scientific basis during the past few decades" coupled with the ability of agricultural research workers and "others in many specialized branches of science" to mobilize and extend resources quickly to meet new emergency problems and the tremendous needs of today."

"The ability of the United States progressively to increase its production of food, feed and fibre during the past three years is due to a great extent to the large accumulation of data from past research and the all-out application of research agencies to the job of interpreting and applying accumulated facts which could be disseminated by extension agencies to the farmers, who were confronted with what looked to some an almost impossible task."

"It was relatively easy to determine what increases of certain products were needed, but among other things, such as supplies of labour, farm machinery, fertilizer, etc., the accomplishment of the goals has involved greater efficiency in using soil resources; superior seed stocks of improved crop varieties; improved growing, harvesting, distribution and utilization practices; improved animal feeds and feeding, and reduction in losses from insect pests and diseases. In meeting the demands for more livestock, it was necessary to produce more feed, to make maximum use of pasture and roughages and to provide substitutes for some feedstuffs."

"As examples illustrating how scientists have cooperated in attacking regional and national problems connected with the war, may be mentioned the nation-wide cooperative study of how best to conserve nutritive values of sixty-nine different foods which is participated in by forty-six experiment stations and the Department of Agriculture; and the cooperation of many State stations and the Department of Agriculture in determining where kok-saghyz, the Russian rubber-bearing dandelion, and various fibre and drug plants can be grown. Many important agricultural problems during the past few years have been investigated by the nine Bank-head-Jones regional research laboratories which were organized in cooperation with the State agricultural experiment stations and were located in different sections of the country. Valuable knowledge has already been obtained in the fields of vegetable breeding, salinity in irrigated soils, animal and poultry diseases, pasture improvement, soybean production, sheep and pig breeding and the interrelation of soils, plants and animal nutrition."

"Similarly, the four regional laboratories at Albany, New Orleans, Philadelphia, and Peoria, organized to find new and industrial uses of farm products and by-products, have already made discoveries important to the war as well as to our domestic economy."

"Thus, although faced with difficulties in retaining an adequate number of trained research workers and in maintaining essential facilities during the past two years, the experiment stations, the U.S. Department of Agriculture, universities and other research institutions have solved many new problems and have increased the volume of their services." Among recent accomplishments may be listed the discovery of ways and means of growing, harvesting and processing crops yielding certain drug, fibre and rubber goods which at one time could only be obtained from foreign countries; the invention of new labour-saving machinery to meet the shortage of labour; the dehydration of foodstuffs in order to conserve shipping space and the development of new and original methods of freeing and protecting men from body lice and mosquitoes. "Chemists, physiologists and other scientists have solved a host of "specific problems" such as developing more efficient methods of obtaining alcohol from wheat; preventing the deterioration of fabrics for domestic use and military purposes; making new plastics derived from wood and from crop residues and modifying sterility and increasing the milk flow of animals by the use of hormones."

"Home economists, among many other activities, have investigated and given advice on how to cook food on a large scale, under conditions such as those found in service camps, so as to achieve great savings of nutrients; have calculated the nutritive values of available and potential food supplies as a guide for production and rationing policies; have found ways to use

alternate foods and fibres and distributed an immense amount of information on how to get the maximum use out of products no longer made in liberal quantities."

"Much work, in the aggregate, has been done on the problems of nutrition, particularly in relation to protein supplies for both human beings and livestock. With shortages of protein feeds, especially of animal origin, a limiting factor in livestock production, physiologists have had to determine how little could be used and to what extent one source of protein could be substituted for another in rations. Chemists and others have worked on the problem of recovering as much valuable protein as possible from distillery by-products instead of having it go to waste. In the case of diets for human beings, one of the main problems has been to work out ways of using more protein directly from plant sources rather than have it converted first to meat in the animal organism. Work done with soybean, peanut and cottonseed products has shown the nutritional value of their proteins, and home economists have developed many recipes and formulas for the use of soybean products. In this connection, recent research on amino acids promises to give us a more accurate knowledge of protein nutrition than we have yet had."

"The few examples just given illustrate the originality, ability and cooperativeness of agricultural scientists. They show that agricultural research, both abstract and applied, carried on during peace times has been immensely useful in time of war. Naturally applied science must be stressed in all agricultural research carried on by public agencies. But the development of basic information and the discovery of principles upon which practice can be based make it possible to arrive at a more steady, direct and satisfactory solution of problems. The whole progress of science and the application of its findings depends on filling in the gaps in our knowledge of the nature of things. There is a very definite limitation indeed to the extent of progress which can be made without a backlog of fundamental knowledge."

"An especially striking example of the importance of supporting fundamental research is found in the remarkable results now being obtained with penicillin in preventing or clearing up infections. All the funds that have been provided for many years to study the growth, reproduction, physiology relationships and life histories of the many species of plants grouped under the general term "fungus" would be justified by this one discovery, even if all such work had not already been paid for very many times over by economic applications of the results of critical research. Because of the knowledge of investigators versed in the cultivation of fungi on a large scale, it will now be possible to produce large quantities of penicillin and save the lives of thousands of people."

So much for the fruits of past research and for what agricultural research is doing now. What of the future?

More than in any other crisis this war has proved that possession of scientific knowledge is a matter of life or death and this scientific knowledge would not have been available had it not been for the support given to research pertinent to agriculture in the United States during the past years and decades. The war has proved that no wiser investment was ever made by the American public. Dr. Auchter expressed the hope that "no one will ever again be tempted to doubt the value of research to the point where public support is reduced, so that vigilance slackens and effort lags. Also, in the event of another war he said that "success will again depend in no small measure on how well equipped the nation would be with knowledge developed in times of peace."

"It is well recognized to-day that research of all kinds will have to be enlarged and accelerated in every nation that hopes either to retain or to advance its present standard of living. Science truly is one of the great frontiers of a much shrunken world, and any nation that neglects the exploration and development of this frontier is almost certainly hazarding its future—its potential share in the fruits resulting from technological advances, if not its independent existence."

"There will be a great need for research in the years ahead.... Among many things with which we shall certainly be vitally concerned are these:

"(1) Improved nutrition for human beings will be one of the great objectives of the future.... It must be one of the responsibilities of those concerned with animal and human nutrition to expand their research and continue to provide authoritative information in this field."

"(2) In the broad field of plant and animal production, there will be many problems. It would be valuable to build up a detailed, systematic world geography of soils, climatic conditions, varieties of plants and methods of plant and animal production. Much of our knowledge of the development and growth of plant and animal organisms has come from agricultural scientists; we shall be expected to advance on that front, particularly in the direction of still greater control by such methods as breeding and the use of substances that regulate growth and functions. In this connection, world exploration to obtain and then maintain plant and animal germ plasm for breeding purposes will be of decided importance. We are likely to have abundant supplies of cheap nitrogen after the war; our crop rotations and systems of farming will need to be re-examined in the light of the changed fertilizer situation. In any future additional irrigation and drainage projects that may be developed, research by engineers, soil scientists and economists should be carried on in advance so that the causes of past failures may be avoided. The increasingly close contact between countries will mean new problems of insect, parasite and disease control; how can we cope with them, and in particular adapt for civilian use the revolutionary new methods of combating insects that have been

developed during the war? Research is needed leading to the development of new and improved immunizing agents for many specific animal diseases."

"The nutritional quality of agricultural products will receive increasing attention. We must follow up the promising leads we now have for improving nutritional quality by the proper choice of climate, soil management, cultural practices and plant breeding. We must also continue to investigate means of conserving such quality once it has been obtained. Only about half of all the milk solids dairy farmers produce are used directly as food for human beings; how to make it possible to use more of these valuable products is a problem of world-wide interest. There are literally thousands of identified species and strains of micro-organisms many of which might be utilized to make valuable new pharmaceuticals, foods and industrial products; would it not be worth while to make a systematic survey of the possibilities in this field, extending the work already started with certain yeasts as relatively cheap sources of protein?"

"(3) Research in engineering and electrical and mechanical problems will be needed more than ever for such things as the perfection of home freezers, further improvements in refrigerated transportation, developing the possibilities in air transport of agricultural products, the use of the newer building materials for farm structures and improvements in the functional adaption of farm buildings. Might it not be possible to develop complete sets of labour saving machinery at reasonable prices for farms of different sizes and types? Although entirely an engineering problem, much will need to be done to develop dehydration, quick-freezing and canning of foods to meet the changed needs and conditions of the post-war world . . ."

"(4) Many of the problems mentioned have both immediate and long-time aspects. In addition, there are many that will be urgent as soon as the war stops and that should be solved as far as possible before that time. For example, how can we best adapt for agricultural use certain equipment that will no longer be needed for military purposes? How can we best use training camp areas—land, buildings and other improvements—for agricultural and rural industries, and especially for aiding and training returning soldiers?"

"(5) Hundreds of millions of tons of crop residues are produced annually on the farms of this country. We should have a more vigorous research programme to exploit this tremendous resource more intelligently for soil improvement, feed and such industrial products as building materials, fuel and chemicals. Some of the products developed might be made right on the farms while others could be the basis for local industries."

"(6) Last, but surely not least, we need to think seriously about much more basic research in several fields of science. For instance, our knowledge of such substances as starch, proteins, lignin, hemicellulose, enzymes, hormones and vitamins is still hardly more than rudimentary."

"The list of suggestions just made is by no means exhaustive, but it does represent pressing and important lines of work. It would take careful thought, critical judgment and evaluation by many people of experience to determine what we need to do first and most after the war. Wartime developments and the prospective needs of farmers and consumers must be continously weighed and considered. Thinking along that line is being done in connection with cooperative efforts at post-war planning, but as much attention must be given to the natural sciences as to economics."

"Post-war planning in the social sciences is, of course, very important. Many urgent problems demand attention, such as those involving desirable adjustments in land tenure, cooperative institutions, shifts of population, improvement in marketing methods and various rural social institutions. The urgency of these problems, however, serves to emphasize the need for the closest possible integration of planning and research in all the sciences, natural and social alike, and a careful avoidance of too great compartmentalizing, or departmentalizing, of the planning and the implementing of the plans. There is also need for careful thinking and planning with respect to methods of extending the results of research to industry as well as to agriculture, particularly as they pertain to the utilization of farm products."

"Agricultural research after the war can no longer be concerned with the needs of the United States alone; it must relate our needs to world conditions. This will be true whether or not there is close post-war collaboration among many countries. It will be doubly true if any such plans for cooperation are put into effect as those disscussed at the United Nations Conference on Food and Agriculture held at Hot Springs. The delegates at Hot Springs paid a great deal of attention to agricultural science. If a permanent organization results from the conference, as now seems likely, agricultural science must be given critical attention in its work...:We are certain to have a world in which it will play an even more positive and dynamic part than it has in the past; and if recommendations such as those made at Hot Springs are carried out, even very gradually, by a permanent international organization, agricultural science will be consciously used, on a scale never before attempted, to help bring about world-wide freedom from want and more lasting peace."

"Agricultural science has done much to shape the world we live in. It is playing an important part in the solution of our present problems. It is ready, able and eager to make the greatest possible contribution in the post-war world."

VIRUS DISEASES OF CACAO IN TRINIDAD

BY

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VIRUS diseases of cacao have been described (2) from the Gold Coast, where "Swollen-shoot" has been known as a virus disease since 1940. No virus diseases of cacao have been reported previously from elsewhere. Leaf symptoms resembling those of Swollen-shoot were first noticed at River Estate (near the western end of Trinidad's Northern Range) in November 1943 in several fields of cacao varying from 5 to 25 years old. Soon afterwards, similar symptoms were found in the nearby Santa Cruz and Maracas valleys. Considerable variation was at first attributed entirely to different host reactions, since Trinidad's cacao is notoriously variable, but transmission experiments have now shown that two viruses (or strains) are present. Until cross-immunity tests have proved them to be related, it is preferable perhaps to describe them as distinct viruses.

Red Mottle Virus

SYMPTOMS

The most obvious symptom of this virus is the presence of red pigment along the sides of some of the main veins in the leaf. The young leaves of cacao range in colour from pale green, through pink to dark red; the veins may be red or green. As the leaf matures, the red pigment gradually fades and the leaf turns green. In a normal leaf this transition occurs evenly over the whole leaf; when infected with Red Mottle the pigment remains along the sides of some veins after the rest of the leaf has turned green, and sometimes remains visible as a faint "shadow" in a mature leaf. When formed in the leaves of otherwise unpigmented trees, the mottle is much more conspicuous than in deeply pigmented types. Sometimes the mottle takes the form of a net-work over the whole area of the leaf, but usually the red pigment is confined to part of the leaf, and associated with the mid-rib or a few main veins giving a feather-like pattern.

In some clones the red mottle appears on young pods, providing a useful symptom as it remains until the pod is about one-third grown. Diagnosis by leaf mottle is dependent on the presence of young leaves.

In addition to the red mottle, mosaic usually develops in some of the leaves on an infected tree. The most common form of mosaic is illustrated in Fig. 1. Small areas are cleared along the sides of the main veins, often in the angle where veins join. Finer veins are sometimes cleared, but the clearing is uneven, tending to break up into distinct patches. This mosaic is most obvious in young leaves, but unlike the red mottle, it remains in mature leaves in which the cleared areas turn yellow.

Crinkling of the leaf is often associated with the virus, as is necrosis of the leaf-tip, but neither are reliable symptoms in diagnosis. No swellings have been found on the branches of infected trees.

TRANSMISSION

Eleven seedlings out of 22 grafted with budwood from infected trees have shown symptoms on the stock. All controls have remained healthy. The interval between grafting and the appearance of symptons varied from 94 to 119 days with an average incubation period of 98 days.

HEAT INACTIVATION

The virus was not inactivated in budwood immersed for varying intervals up to 10 minutes in water thermostatically controlled at 50°C. All buds were grafted successfully; those treated for 4, 6 and 8 minutes grew, but most of those treated for 10 minutes died. Symptoms have appeared in all groups. Longer immersion at a lower temperature also failed to inactivate this virus. Transmission occurred from budwood treated for 45 minutes at 43.4°C.

Vein-Clearing Virus

SYMPTOMS

The symptoms of this virus differ from those of Red Mottle in that vein-clearing is very pronounced, and often extends to the fine veins, so that a yellow net-work forms all over the leaf (Fig. 2). Clearing runs along the sides of the veins without breaking up into separate spots. No yellow mosaic, red mottle or swellings are associated with this virus, but leaf crinkling is more pronounced than with Red Mottle.

TRANSMISSION

Symptoms have appeared on all 4 seedling stocks grafted with budwood from an infected tree. Two seedlings continued normal growth after budding, 1 developing symptoms in 45 days and the other in 60 days, indicating a much shorter incubation period than that of Red Mottle. The other two seedlings developed symptoms on the first flush of leaves formed after budding, but this was delayed till 119 and 130 days respectively after grafting.

Virulence

It is too early to make a definite statement on the virulence of these diseases. It is clear that there is considerable tree-to-tree variation in tolerance. Some trees may suffer noticeable defoliation followed by dieback, while others remain apparently unharmed. That this variation is genetical is indicated by the behaviour of I.C.S. clones at River, where differences in symptoms are greater between clones than between trees in the same clone.

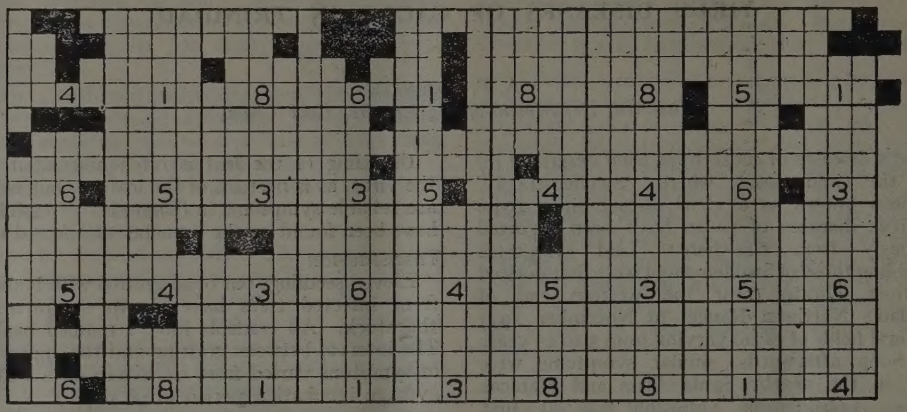

Fig. 4. Distribution of virus infection in Expt. CRB1 at River Estate. Infected trees shaded. Numbers refer to I.C.S. clones.

Spread

Both viruses appear to spread in a manner similar to that of the Swollen-shoot virus on the Gold Coast (3). There is the same occurrence of groups of infected trees, indicating tree-to-tree spread along rows, and of individuals or pairs of infected trees indicating the formation of new scattered outbreaks (Fig. 4).

Assuming that all plants in the block of I.C.S. clones at River Estate (1) were healthy when planted, the rate of spread is sufficiently rapid to be alarming. Set 1 has been surveyed tree-by-tree, and out of 576 trees 45 are showing definite symptoms (Fig. 4). Several more are suspected, and thus 7.8 per cent. is probably an underestimate of the degree of infection. When it is recalled that the rate of spread will almost certainly accelerate as the virus becomes more concentrated, this is a serious figure for a six-year-old field. There appears to be little infection yet in the younger blocks to the south; whether this is due to their age or to the direction of spread is doubtful, but the latter explanation is supported by the fact that most of the infection in Set 1 are in the northern half.

Distribution

Until a careful search has been made on most estates it is uncertain what areas in Trinidad are still uninfected. At present, the viruses appear to be confined to the western end of the Northern Range, with the Maracas valley as the most easterly point. They are most prevalent in the Santa Cruz valley, where symptoms are obvious in every field inspected. Only the Vein-clearing virus has been found in the Maracas valley, in several scattered patches, the largest consisting of at least 40 infected trees. Both viruses occur together and in separate outbreaks in the Santa Cruz valley, with Red Mottle more prevalent. In Diego Martin, Red Mottle predominates; symptoms resembling the Vein-clearing virus have been seen on a few trees, so both viruses may be present.

Cacao on the Paria peninsula of Venezuela was carefully searched, and since no sign of these diseases was found it appears unlikely that they have spread from the mainland (4).

Summary

1. A description is given of the symptoms of two new graft-transmissible virus diseases of cacao, Red Mottle and Vein-clearing.

2. Their manner of spread and distribution in Trinidad is described briefly.

Acknowledgments

I am indebted to Mr. R. E. D. Baker for his co-operation, to Professor E. E. Cheesman for the greenhouse facilities of the Department of Botany at the Imperial College, and to Mr. J. G. Davies for Fig. 1.

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Fig. 1.—*Symptoms of Red Mottle Virus.* Cleared patches on veins; red pigment remaining at sides of mid-rib and main veins. (Transmitted light: natural size).

Fig. 2.—*Symptoms of Vein-clearing Virus.* Many veins cleared giving yellow network. (Transmitted light; natural size).

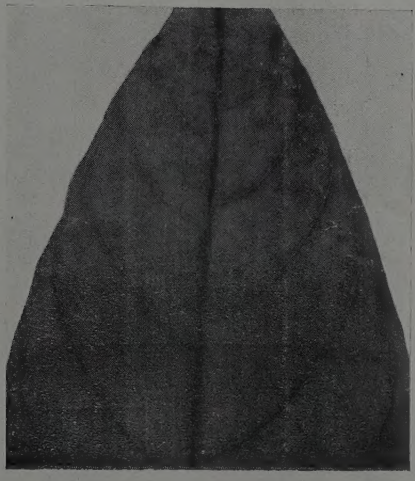

Fig. 3—*Normal Leaf.* (Transmitted light: natural size).

THE ARTHROPOD FAUNA OF SOME TROPICAL SOILS

With Notes on the Techniques Applicable to Entomological Soil Surveys

BY

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Every acre of every soil—save possibly the sands of beaches and deserts—is the home of many millions of insects, mites, and other members of the Phylum Arthropoda. These animals, ranging in size from less than 0.1 to well over 50 millimetres in length, exert a very considerable effect both on the soil in which they live and on its flora. It is in consequence of importance to the agriculturist to know something of the faunal content of the soil he farms.

It is the purpose of the present paper firstly to describe briefly the most important types of Arthropods encountered in tropical soils, and secondly to review the techniques at present available for assessing them.

I. The Soil Fauna

In this section an attempt has been made to outline what is known of the types and numbers of Arthropods inhabiting cultivated or virgin soils in the tropics, and wherever possible notes have been added on the effect which a particular type of insect or mite has on the soil it occupies.

1. *Subphylum Onychophora*

This subphylum consists of a single genus, *Peripatus*. Sparsely distributed over the tropics, members of this genus are slug-like in appearance and spend their lives on the surface of the soil under litter, rotting bark, stones, &c. By no means common, Peripati are of no economic importance.

2. *Subphylum Crustacea*

The soil inhabiting members of this subphylum are limited to one order, the Isopoda, and consist of the common sowbugs and wood-lice of world wide distribution. As a rule, they feed upon decaying vegetable matter, but sometimes attack young plants. Van Zwaluwenburg (31) observes that they have been known to injure sugar-cane roots when kept in captivity, and Berwick (3) states that they are common in sugar-cane soils in Trinidad. The author has found them occurring at rates as high as 2.1 millions per acre in the surface crumb layer of a cacao field in Trinidad, though generally they are present at rates of not more than 0.2 millions per acre. In all, Isopods are probably of little direct economic importance.

3. *Subphylum Myriapoda*

Centipedes and millipedes are common inhabitants of decaying vegetable matter and rich, humic soils. Generally, the Diplopoda, (millipedes), are feeders on decaying vegetation, and Dammerman (4) cites that in temperate zones they are useful as producers of humus. The Chilopoda (true centipedes), are largely carnivorous in habit and, save where they occur in large numbers and destroy harmful and beneficial insects, are of little economic importance.

4. *Subphylum Insecta*

It has been shown—McColloch (16)—that probably 95 per cent. of all known species of insects spend at least a part of their life history in the soil. For this reason, and because many insects are pests of considerable importance, it is proposed to deal with the group order by order.

(*a*) *Thysanura.*—"Silver fish" are common, according to Berwick (*loc. cit.*), on the soil surface in sugar-cane and cacao fields. In the author's experience, members of the family Japygidae are commoner in areas of savannah than in cacao or forest, occurring usually at a depth of about 3 inches. Van Zwaluwenburg (*loc. cit.*), in Hawaii, states that undetermined species of Japygids occur as abundantly as 218 per square foot (9.5 millions per acre), being found in greatest abundance at depths of from 5 to 7 inches below the soil surface. The function of Thysanura in the soil is not fully understood, and little can be said other than that the order is largely saprophagous in habit. Japygids have shown a tendency to eat tender root cortex in laboratory experiments, and it is likely that they could become a pest if their normal food supply became exhausted.

(*b*) *Protura.*—These are minute and little-known inhabitants of damp soils and mosses. Their function and methods of feeding are obscure, and they are of no economic importance.

(*c*) *Collembola.*—Springtails occur in immense numbers in all types of soil and under all types of vegetative covering. In many soils they comprise 50 to 70 per cent. of the total insect population and, according to Eliot Williams (28), form the base of the animal food chain. Collembola occur in greatest numbers in litter on the soil surface and in the superficial root mat-soil crumb layer. Van Zwaluwenburg (*loc. cit.*) has shown that members of the genus *Isotoma* can be dangerous to fine cane roots, especially when the normal supply of dead and rotting rootlets from a past season's crop is exhausted.

(*d*) *Orthoptera.*—This order contains members of great economic importance that spend varying periods of their life histories in the soil. Locusts and grasshoppers, especially when in swarms, have a considerable local effect on the soil through their habit of drilling holes in the surface in which to deposit their eggs. Mole crickets spend both

nymphal and adult stages burrowing in the soil, thereby increasing aeration and drainage capacity, and attack the stems of young plants—especially vegetable crops—at ground level.

(*e*) *Dermaptera.*—Many species of earwigs spend the daytime in the shelter of the soil, either hunting at night on/or in the soil, or actively flying about in search of food. Most species are actively predaceous, devouring flies with great relish. Some species are plant feeders, and outbreaks of *Forficula auricularia* occur from time to time in Europe and the United States. On the whole, however, the Order is of little economic importance.

(*f*) *Isoptera.*—Termites occur in enormous numbers in many soils throughout the tropics and subtropics, and most of the known species are essentially soil dwellers. As such, they exert a profound influence on the soil, both in the formation of humus and in the actual mechanical excavations and tunnellings characteristic of the order. Termites attack growing plants relatively little, but a few species are important pests of, for example, rubber in Malaya, where *Coptotermes curvignathus* (*Termes gestroi*) caused considerable economic damage until control methods were applied (Richards (20)).

(*g*) *Corrodentia.*—The sub-order Psocida are common inhabitants of decaying moss, bark and other forms of vegetation. They mostly appear to be fungivorous in habit and, in the author's experience, occur at rates varying from 0 to 1.4 millions per acre under the litter in cacao fields. Berwick (*loc. cit.*) states that: "They apparently occur deep in the soil; most of those found in the fallow plot were at least 7 inches below the surface" (dry season sampling). Except in so far as their fungivorous habit may be important in the economy of the soil microflora, the Corrodentia are of little importance to the agriculturist.

(*h*) *Thysanoptera.*—The Thrips are largely plant feeders, sucking the sap of the host plant and causing serious damage to many crops. Some species live in the soil or under surface litter and are probably fungivorous in habit. Others, living in the same environment, are predaceous, sucking the body fluids of young mites. The author has found thrips of all stages of maturity, but mostly nymphal, in cacao and savannah areas at rates of 22.54 and 1.56 millions per acre respectively. It has not as yet been possible to identify the specimens noted in the former case, but the population is so high that economic damage to the cacao is possible, if not actually occurring.

(i) *Hemiptera.*—Relatively few insects of the order Hemiptera live in the soil. Many that do, however, are of extreme economic importance. Aphids, attacking the root systems of many types of grasses, legumes, and composites, are common in some cultivated soils, often being carried to the roots of the right host plants by ants. Scale-insects and mealy-bugs are temperate soil pests of importance, and likewise are often "farmed" by ants. Little work has as yet been done on this group in tropical soils. Berwick (*loc. cit.*) cites Coccids as being present at the rates of 50 millions per acre in sugar cane, and 30 millions per acre in cacao, and suggests that considerable damage must be done to the crop by such high populations. The author is at the present time investigating a new scale insect of the Subfamily Ortheziinae that appears to be present in declining cacao estates in Trinidad in quantities varying from a few hundred thousands to over 20 millions per acre.

Of the Heteropterous families occurring in the soil, Lygaeids, Mirids, Reduviids, Pentatomids, Cydnids, Aradids, Enicocephalids, Anthocorids and Cryptostemmatids have been noted by Eliot Williams, Berwick and the author. Of the Homoptera, Flatids, Jassids, Derbids, Achilids and Cercopids occur in small numbers. Of the Cercopids, an important example is *Tomaspis saccharina*, the Trinidad sugar cane froghopper. This lays its eggs in the soil at the base of cane stools, and Pickles (19) has, through systematic and careful investigation, been able to foretell froghopper attack by counting the eggs contained in soil samples.

(*j*) *Neuroptera, Mecoptera, Trichoptera.*—These three Orders all contain soil inhabiting larval forms, but are of no economic importance and do not occur, generally, in large enough numbers to have any important mass effect on soil structure.

(*k*) *Lepidoptera.*—The Lepidoptera include many pests which spend part of their life cycles in the soil—army worms, cutworms and bollworms alone are annually responsible for millions of pounds worth of damage. It is especially with such relatively large and easy-to-extract insect larvae as these that much useful soil survey work should be done. Strength is lent to this view by the possibility of foretelling pest years in time to apply control methods—it has, for some years past, been possible to foretell cutworm attacks in Canada, and much money and trouble have been saved to farmers through the population studies carried out by King (13) and Seamans (22), on this problem.

(*l*) *Coleoptera.*—The beetles comprise an extremely important fraction of the soil fauna, both from economic and ecological standpoints. Many members of the families Staphylinidae, Scarabaeidae, Carabidae, Silphidae, Trichopterygidae and Tenebrionidae spend both their larval and adult lives in the soil, and some do great economic damage in both stages. Others—in particular many Chrysomelids—spend their larval and pupal stages in the soil and emerge to do great damage to crop plants before returning to the soil to lay their eggs. Elaterid and Scarabaeid larvae probably do more economic damage to setts and young plants than all other Coleopterous families together. Elaterid larvae have been incriminated in damage to cane setts in Hawaii (31), and Cuba (23). Scarabaeids ("May", "June" and "Dung" beetles), include the

Japanese beetle, *Popillia japonica*, whose larvae burrow into tubers and adults eat the foliage of the host plants; the Anomala beetle, *Anomala orientalis*, whose larvae do considerable damage to cane stools, members of the genera *Lepidoderma* and *Lepidiota*, which are amongst the chief cane pests in Queensland, and many other serious pests. McColloch (16), has pointed out that June beetles much prefer heavily manured soils, which also attract their larvae. In advocating a heavy dressing of farmyard manure in regions prone to Scarabaeid attack, the agronomist may unwittingly be helping a serious pest to reach dangerous proportions.

The family Staphylinidae, probably the most characteristic coleopterous soil inhabitants of tropical forest and plantation soils, deserve mention because of their predominantly predaceous habit. They are probably the most important single family in preventing an uncontrollable increase in the Mite-Springtail complex that forms their chief food supply. The Trichopterygidae deserve mention in so far as they are largely fungivorous in habit and occur in relatively large numbers in all soils sampled by the author in Trinidad (highest count obtained: 6.72 millions per acre), and in some 85 per cent. of the small quadrat samples taken by Eliot Williams (*loc. cit.*) in Panama.

(*m*) *Hymenoptera.*—Many Vespoids, especially of the families Bembecidae, Eumenidae and Sphecidae, some Chalcidoids, Cynipoids and solitary Apoids burrow into the soil either to pupate or to build nests. They are of little significance in the soil faunal complex. By far the most important soil inhabiting Hymenoptera are the ants (Formicoidea). Ants occur all over the world in colonies, often of extremely large size, and the sum total of soil moved annually by them must almost equal that moved by termites. Besides building their nests in the soil, ants exert a profound general influence on the natural economy of the areas they inhabit—both as scavengers and predators. Quite apart from the the Total Effect exerted by ant colonies on an area, individual ant species are important as vectors of Aphids, mealy-bugs, Membracids, and other Hemipterous insects. Ants of the subfamily Attini are important as defoliators, many types of cultivated plants being susceptible to attack by "leaf cutters". Like many other pests, ants find it harder to damage healthy than weak plants, and McColloch (16) cites an interesting case where the Kafir ant did quite considerable damage to surface planted sorghum but neglected nearby listed stands.

Problems of sampling for ant population investigations are similar to those encountered with termites, and are discussed below.

(*n*) *Diptera.*—Apart from an occasional adult Phorid and freshly emerged adult Chironomids, Psychodids and Cecidomyids, the Diptera are represented in the soil solely by their larval and pupal stages—many of which emerge as important pests. Of these, fruit flies (Trypetidae), blow flies (Calliphoriinae) and Tsetse flies (Tachiniinae) are worth mention. Occasionally Anthomyid and Stratiomyid larvae are encountered, but there appears to be no tropical Tipulid as dangerous to crops as the temperate Leatherjacket. Amongst the Dipterous larvae found by the author in Trinidad cacao soils, the family Ceratopogonidae is well represented, and several adults of *Forcipomyia* spp., probably important as cacao pollinators, have been found in a newly emerged state. There are many problems in the elucidation of the life cycles of economically important Diptera that cannot be adequately solved without critical soil work.

5. *Subphylum Arachnida*

(*a*) *Orders Pedipalpida, Scorpionida, Chelonithida, Phalangida and Araneida.* These five Orders are predominantly inhabitants of the litter and trash on the soil surface. Most species are actively predaceous and are important factors in the food cycles of soil insects. They are relatively unimportant from an economic standpoint.

(*b*) *Order Acarina.*—The mites constitute the the most numerous and widespread group of soil Arthropods, forming often as much as 60 to 70 per cent. of the total fauna of many soils. Although minute in size—often less than 0.1 mm. long—the Acarina make up in quantity what they lack in individual size, and the sum total of their effect as components in the break-down of vegetation to humus and in channelling the superficial layers of the soil must be enormous. Since few species directly important as crop pests live in the soil, little work has been done on the biology and ecological effect of the Earth Mites and, in view of their obvious significance, it is hoped this position will soon be rectified.

In order to give some idea of the composition of the Arthropod soil fauna of some tropical localities, Table I has been drawn up. It should be noticed that the results from Berwick's (*loc. cit.*) and Eliot Williams, (*loc. cit.*) investigations have been converted into terms of "millions per acre" in order to render them comparable with the author's results. Tullgren-Berlese funnels were used to extract the fauna by all three workers, but it should be noticed that Eliot Williams' results are probably too low since his samples only received a 6-hour treatment in the funnels—"a longer treatment would have been desirable". All the results given in this Table are the means of sufficiently large number of samples to render the population figures of some value as an index of the faunal content of the areas sampled.

II. Techniques Applicable to Soil Fauna Investigations

In the preceding section a summary has been given of the vast assemblage of animal types that are encountered in most soils the world over. It will be appreciated from this summary that

Table I

The Arthropod Soil Fauna of Some Agricultural and Forest Soils in Trinidad and Panama

Results expressed in terms of "millions per acre"

Investigator	Elliot Williams (*b*)	Strickland					Berwick		
Country and Season	Panama: Wet	Trinidad: Wet		Trinidad: Dry			Trinidad: Dry		
Type of Land Sampled	Natural rain forest	Natural rain forest		Savannah	Plantation Cacao		Plantation Cacao	Sugar Cane	Arable fallow
Depth of Samples	Litter only	Litter	0-3″	0-3″	Litter	0-3″	Litter + 0-9″	0-9″	0-9″
Number of Samples	23	15	15	60	50	50	60	60	60
Isopoda ...	0.59	0.13	0.04	0.05	0.17	0.80	2.75	3.12	0.04
Arachnida other than Acarina ...	0.59	0.34	0.33	0.13	1.96	2.41	94.17	151.96	28.64
Acarina ...	6.94	43.54	32.51	53.42	65.52	17.67			
Myriapoda ...	0.81	0.84	0.48	1.97	0.49	0.62	0.08	5.79	2.07
Thysanura ...	0.23	0.04	0.01	1.12	0.02	0.20	0.02	1.84	1.69
Collembola ...	9.26	(*a*) 6.37	(*a*) 3.78	17.44	28.00	12.46	22.76	30.67	14.99
Orthoptera ...	0.08	0.28	0.01	0.02	—	—	?	?	?
Isoptera ...	0.05	2.39	15.64	0.11	—	0.04	?	?	?
Thysanoptera ...	< 0.01	0.13	0.13	0.17	3.25	1.02	?	?	?
Corrodentia ...	< 0.01	—	< 0.01	0.14	0.25	0.07	?	?	?
Hemiptera—									
Coccids ...	0.04	0.76	1.14	1.86	0.14	0.14	11.95	19.75	0.23
Others ...		0.34	0.13	1.26	0.21	0.31			
Coleoptera—									
Larvae ...	0.22	0.42	0.27	0 84	1.46	0.56	?	?	?
Adults ...	0.47	0.38	0.78	1.76	2.60	1.68	?	?	?
Lepidoptera—									
Larvae ...	0.03	0.02	0.02	0.01	0.01	—	?	?	?
Adults ...	—	0.01	0.01	0.06	—	—	?	?	?
Diptera—									
Larvae ...	0.12	1.88	0.90	0.40	1.40	0.29	?	?	?
Adults ...	0.09	0.21	0.15	0.25	0.11	0.31	?	?	?
Hymenoptera other than Formicoidea ...	< 0.01	0.18	0.09	0.06	0.04	0.04	17.04	24.97	0.42
Formicoidea—									
Larvae ...	0.01	1.12	0.18	0.58	1.12	0.63			
Adults ...	< 6.64	4.84	7.34	6.51	23.98	3.92			

(*a*) Probably too small. Mean of 10 samples taken in 2 Forest Reserves.

(*b*) Means of small and large quadrats, extracted by Berlese funnels, only.

the difficulty of extracting and counting the fauna from even a comparatively small volume of soil—especially if it is of wet and sticky clay—is enormous. In this section the techniques implicit in accurate soil census work are discussed in some detail, and conclusions are drawn which it is hoped will be of use to those contemplating such work in the future.

THE PRINCIPLES OF SAMPLING

The statistical principle of random sampling must be adopted in all faunal survey work in which a quantitative result is desired. If the samples are being taken as representative of a particular soil type or floral environment, the area sampled must be large enough to include any local variations that may normally occur in that soil or environment—ideally a number of different areas, basically identical but differing in minor factors, should be sampled separately.

Before a decision can be made on the number and size of samples to be taken in any survey, some indication must be obtained as to the frequency of occurrence of the animals to be estimated—more samples will have to be taken to obtain a valid estimate of a rarely occurring form than for a commonly occurring species. Quite apart from magnitude of population, patchiness of distribution must be considered. It is clear that a sampling technique designed to give an accurate estimate of the cutworm population of an area will not necessarily give a true picture of the social insects in that area. Generally speaking, ants tend to occur in large numbers in one sample of a series, and a totally erroneous result is likely to be obtained unless the estimated population is expressed as the mean of a large number of samples. In the last analysis, the volume of soil that can be handled in a given time is the deciding factor in sampling. Per volume of soil examined, a 6-inch cube sample probably gives a less accurate result than a 4-inch diameter core of the same depth (Yates and Finney (30)), and in most cases it is advisable to increase the number of samples taken at the expense of a decrease in size of the individual samples.

SAMPLING TOOLS.

Many devices have been evolved for taking faunal soil samples. They are of two main types: (1) A system of plates, or plates and collars (Morris (17); Jacot (10)), which enable accurately sized samples to be taken with comparative ease, and (2) Circular metal cylinders of varying diameters that can be screwed or knocked forcibly into the ground and withdrawn with the sample enclosed in the tube (Pickles (19); Finney (7)). The author favours a 4″ diameter core auger, as used for making the hole in golf greens, recommended by Finney (*loc. cit.*),—its advantages in light weight, speed of operation and ease of cleaning (an important consideration in heavy clay land at the height of the rains), rendering slight loss of absolute accuracy in sample depth a minor consideration.

EXTRACTION TECHNIQUE

The most difficult problems to be faced in biological soil work are those connected with the extraction of the fauna from soil samples, and it is the difficulties encountered in the extraction process that account in great part for the small amount of quantitative work done up to the present on soil fauna. There are basically 5 methods by which this process of extraction can be achieved, with variable success:

(1) *Manual Examination of the Dry Soil.* The soil sample is broken up by hand or by a mallet, and shaken in a coarse meshed sieve. As the particles fall through onto a black sheet, the fauna visible to the naked eye—or with a hand lens—can be picked out and recorded. Wolcott (29), working on pasture land in New York State, observes that this method depends largely on the skill and care of the operator, and that all animals of appreciable size can be extracted from a square foot sample in 1 to 2 hours. Lane and Shirck (15) have evolved a mechanical sifter for extracting wireworms from dry soil samples. They found that a 40 mesh to the inch sieve retained all the small wireworms whereas a 20 mesh sieve let many through. Such a system is more rapid than manual examination as the operator need concentrate solely on picking out the wireworms as they appear. Grigor'eva (9) points out that the number of animals obtained by washing samples through a bank of sieves was 120-250 times as great as by manual examination. In appraising Dry Methods one must remember that a great deal depends on the type of soil being examined—obviously there is a better chance of collecting all the fauna from a sample of dry, light sandy soil than from one of a wet, heavy clay. A psychological factor in manual examination—according to the author's experience—is that when examining 20 to 30 wireworm samples in a day, the number of wireworms found tends to decrease as the afternoon draws to a close! In conclusion, manual examination is rapid, enabling a large number of samples to be examined in a short time, and comparatively clean. It is probably of use for surveys of large insects such as cutworms or leatherjackets, but experience has shown that it is of little use for animals much less than 5 to 6 mm. in length unless unlimited time is available for every careful examination.

(2) *Berlese Funnels* (2). The soil sample is broken up carefully and placed on a coarse sieve fixed inside a water-jacketed funnel. Warm water is run through the jacket and, as the humidity of the soil decreases, the fauna migrates downwards, falls through the sieve, down the funnel, and into a tube of water or alcohol. Tullgren (27) has modified this method by using an electric light bulb suspended above the funnel in place of the water jacket. This drives the negatively phototrophic animals down first, and the rest of the fauna follows as the heat from the lamp dries out the soil. The disadvantages of the Berlese and Berlese-Tullgren techniques are: (1) that pupae, eggs, and animals that encyst as humidity

decreases (Tardigrades, Nematodes) are not affected, and remain in the samples, and (2) great care must be taken to ensure that no insects are trapped inside baked lumps of soil. (Jacot (10) overcomes this difficulty by taking a much larger sample than he intends to examine, transplanting it carefully to the laboratory, and paring it to the right size with a sharp knife. The normal runways through which the fauna moves are in this way kept open, and there is little danger of specimens being trapped) (3). As Jacot (*loc. cit.*) points out, 2 to 3 weeks may elapse before all the fauna has migrated down from the sample. Unless a very large number of funnels is available, this is a distinct disadvantage where survey work requiring large numbers of samples is concerned. (4) Trägardh (26) criticises these techniques on the grounds that " . . . . the biocoenoses of different biotopes differ so greatly in composition and in reaction towards light and low humidity, that it is impossible to draw any conclusions from one sample concerning the treatment of another ". In spite of this criticism, results from the same, or closely allied, soil types are comparable amongst themselves.

Undoubtedly Berlese extraction is of considerable use in work on extremely delicate and minute animals since no mechanical damage to specimens is possible. On the grounds outlined above, however, its use in large scale surveys—except as a means for the further examination of soil residues—is very limited.

(3) *Washing the Samples through Sieves.* Included in this category are a number of methods depending on removing the substratum from the insects instead of separating the insects from the substratum. Morris (17), Shirck (21), Jones (12), King (13) and others have described apparatus, all essentially the same, in which soil samples are placed on a large mesh sieve suspended above one or two further sieves of considerably finer mesh, and washed through with water. The fauna is retained on the finest sieve (*see* Table II) along with a mass of soil particles, the vegetation being held back by the coarse sieves. The residue to be examined is only a small fraction of the original sample and can either be examined " in situ " on the sieve, or the fauna floated off by agitating with salt solution of Sp : Gr : 1.1, filtered, and the filter paper, free of soil particles examined. Where large and robust insects or larvae are being collected, this technique is reasonably efficient. It is useless, however, for very delicate Collembola or mites, the mechanical damage done to the fauna by continual agitation against the sieves often being so great as to preclude identification. Shirck (21) used this method successfully for separating small wireworms from soil samples, and a series of sieves designed to take between 40 and 50 lbs. of soil at a time, is at present being used at the Cambridge University School of Agriculture for the bulk extraction of wireworms for advisory purposes.

Table II

Sieve Sizes used by Various Workers

Worker	Sieve mesh in millimetres			
Daniels, L. B. ...	—	1.00	0.75	—
Edwards, E. E. ...	3.50	1.50	0.50	—
Grigoreva, A. ...	3.00	1.50	1.00	0.20
Jones, E. W. ...	—	—	0.75	0.80
Mabyn Thompson ...	—	—	0.75	—
Shirck, F. H. ...	4.00	1.00	0.75	0.50

(4) *Flotation Extraction.*—A number of workers —Daniels (5), Thompson (25), Edwards (6)—have used the flotation principle to extract insects from soil samples. The samples are broken up by agitating in shallow dishes of water, the soil is allowed to settle, and the water, with the fauna floating in it, is poured through fine mesh sieves from which the animals can be picked off. Ford (8) cut his samples into half-inch thick layers and teased these out under water, using a hand lens to count the insects as they came to the surface. Ladell (14) has invented an ingenious apparatus for extracting the fauna from soil samples. Essentially, his method consists of stirring the sample up in a bath of aerated magnesium sulphate solution of Sp : Gr : 1.1. The fauna, escaping from the agitated soil, is carried to the surface by the stream of bubbles. Coarse vegetation is retained by a large mesh sieve just below the surface of the liquid. As more salt solution is added from an aspirator, the fauna is swept over a lip, through a settling tank, (to prevent deflocculated clay particles clogging up the filter paper), and on to a filter paper contained in a Bruchner funnel. The animals can be picked off from the filter paper with ease. Ladell claims that his apparatus can deal with a $5\frac{1}{2}$—$7\frac{3}{4}$ lb. soil sample . . . " the whole process from taking the soil sample to the examination of residue takes from 30 to 40 minutes ". In practice this estimate should be increased somewhat as the apparatus must be cleaned out after each sample has been treated. The author is at the present time using a modified flotation method for an investigation into the soil fauna of cacao estates in Trinidad. This method consists of bubbling a strong current of air through a half saturated solution of common salt, containing the soil sample, for 5 to 10 minutes. The air compressor is then cut off and sediment allowed to settle. More salt solution is added from an aspirator, sweeping the vegetation and fauna over onto a double thickness of one-hundredth inch mesh muslin. The material retained by the muslin is then washed into a beaker and boiled. This serves the dual purpose of killing the fauna in an extended state, so that identification is simplified, and driving the air out of the vegetation and causing it to sink to the bottom of the beaker. After cooling, 15 to 20 ccs. of kerosene are added to the beaker and the contents well stirred. All those animals with chitinous exoskeletons are taken up by the

kerosene layer and can be decanted off onto a filter paper almost free of contamination. In practice it has been found best to give each boiled sample 3 to 4 treatments with kerosene if much vegetable débris is present, as many small mites tend to adhere to the rotting leaves and cannot be detached without considerable agitation. Each sample, after extraction, is washed into a residue can and covered with the salt solution remaining in the apparatus after the fauna has been washed onto the muslin sieve. When all the samples of a series under examination are in the residue can, they are stirred rapidly with a metal stirring rod for several periods of 1 to 2 minutes, and the sediment allowed to settle. The clear salt solution is then decanted off and filtered. Soil residues from the initial extraction process have, by this treatment, yielded between 2.8 and 4.6 per cent. of the total fauna. Probably a longer time than 5 to 10 minutes bubbling and 15 minutes washing would extract these few animals in the initial process.

(5) *Chemical Extraction.*—Barnes (2), working at Rothamstead, has shown that an emulsion of orthodichlorbenzene in water is highly repellent to most invertebrates. If a dilute solution of this emulsion is sprayed on the surface of the soil over a known area, the fauna under that area will migrate up to the surface as the solution penetrates into their burrows. Any sizeable animals—earthworms, cutworms, leatherjackets—can easily be picked up and counted in a very short time, and any number of samples can be taken without the trouble of carrying bulky bags of soil to the laboratory for examination. Results from this method are accurate enough for advisory work on land where the surface is fairly level, but the results obtained from ploughed land tend to be rather variable. The principle behind the method is one that merits further study and application to the estimation of soil fauna.

Errors

In biological soil surveys absolute accuracy, far from being obtainable, is often not essential so long as the order of magnitude of the population can be assessed with reasonable certainty, and so long as the results obtained by whatever technique is used are comparable amongst themselves. Until recently, no wireworms less than 5 mm. long were included in the totals of Dangerous Wireworms per acre in the British Ministry of Agriculture's wireworm survey. In this case, the error introduced by manual examination, as compared to "wet" examination by washing through a bank of sieves, was sometimes of the order of $\times$ 10 on heavy clay samples. In this case the gross inaccuracy of manual examination was not of paramount importance, since a scheme had been prepared (Petherbridge (18)), showing the amount of damage done to different crops by different wireworm populations determined by manual examination. The fact that 1,800,000 more wireworms per acre were present in a field than had been estimated in the laboratory did not matter from an advisory standpoint. Where greater accuracy is important, a careful technique, coupled with some means of checking residues, is necessary—King (*loc. cit.*), in Saskatchewan, examines his wet residues by means of Berlese funnels.

Soil type is most important when deciding on an extraction technique—a light sand offers relatively little resistance to total extraction, manually, by sieves, or by Berlese funnels. A heavy clay or wet loam is quite a different matter, and it is usually necessary to treat such samples either with a bath of some deflocculating solution such as magnesium sulphate or sodium chloride or by freezing hard and thawing out over a period of 48 to 72 hours.

In all techniques errors are almost inevitable and to counteract such errors great care should be taken that none of the fauna being extracted is lost or damaged through careless handling or cataloguing.

Supplementary Data

Ideally, any survey of a soil fauna should be as much an ecological as an entomological survey and especially important in this respect is as complete an analysis of the chemical and physical attributes of the particular soils sampled as possible. Rainfall and temperature figures—diurnal, seasonal and annual, both for the specific sampling sites and for the sampling districts—should be obtained whenever possible. Other items that should be noted include: the state of the soil on sampling dates—waterlogging, puddling, erosion, &c.—crops on the land, information on the previous year's crops and details of manuring programmes, length of time the land has been under cultivation or, conversely, length of time under grass or secondary bush. All of these factors exert a profound influence on the faunal content of a soil. Stark (24), in a discussion of the relation between moisture content of different layers of forest soil and the insect fauna occurring in them, observes that the presence of different species of insects and their behaviour are closely correlated with the physicochemical, morphological and biological characteristics of each layer, and probably depend chiefly on the degree of absolute humidity. King (13) also points out that in his investigations ". . . there have appeared marked correlations between meteorological factors and the population trends of many species and larger taxonomic groups". It is important to note the "condition" of the land when sampling areas under crops or grass leys. As Jary (11) observes, well kept and rich pastures almost invariably have high wireworm populations, whereas badly kept, bracken infested derelict fields contain few wireworms.

Whilst it is perhaps too much to expect a large scale survey to take account of all the supplementary data mentioned as desirable, chemical analyses, and especially moisture determinations, of the samples should be obtained.

III. Conclusions

From the preceding sections it should be clear that, given adequate facilities, a census of the Arthropod fauna of all types of cultivated and virgin land is a reasonable possibility—in many cases already an established fact—and is often desirable from an agricultural standpoint.

By the selection of a technique adequate for the particular project on hand, but not embodying any of the special refinements that are necessary for very accurate work on micro-arthropods, it should be possible in a few years to amass sufficient data to devise routine methods for the prediction of many major pests which spend a part of their life cycles in the soil. In addition, techniques are available which, although tedious, are capable of yielding sufficiently accurate counts of micro-arthropods for initial work on the effect these animals have *en masse* on the structure and fertility of the soil. It is highly desirable that these two major lines of research should be entered upon—the first in as widespread a manner as possible, the second preferably in a number of different institutes staffed with specialists in the faunal groups concerned. It is hoped that some efforts will be made along these lines as soon as conditions permit.

IV. Summary

1. A list of the most important types of arthropod fauna spending a part or all of their life cycles in the soil is given, along with comments on their direct and indirect importance to the agriculturalist and notes on their frequency of occurrence in some tropical soils.

2. A summary of existing techniques for the taking of biological soil samples is given, and the various methods at present available for the extraction of arthropod fauna from such samples, are discussed.

3. The paper is concluded with a suggestion as to future work on soil fauna.

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POLLINATION OF CACAO IN TRINIDAD

BY

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Review of Literature

The most important contribution to the extensive literature on the pollination of cacao flowers was made by Billes (1) in 1941 when he drew attention to the Ceratopogonid midge, *Forcipomyia* sp. Subsequent investigation has shown that this insect is probably the most important pollinator and therefore directly responsible for the bulk of the cacao crop in Trinidad.

Voelcker (8) has reviewed the literature on pollination up to 1937, at which time it was established that all fruit setting on self-sterile trees and at least half that on self-fertile trees resulted from cross-pollination (9). Speculation on the insects responsible concerned ants, thrips and aphids, these being the only insects found in large numbers in the flowers.

Cope (4) working in Trinidad followed the trends of setting and of insect populations in the flowers of 8 self-fertile and 9 self-sterile trees. He failed to find any significant difference in the insect population of the two types; both showed peaks of setting intensity in July and December, with the self-fertile setting three times as much fruit as the self-sterile trees. The correlation between aphids (*Toxoptera aurantii* B. de Fonsc.) and setting was negative; that between ants (*Wasmannia auropunctata* Rog.) and thrips (*Frankliniella parvula* Hood) positive. He points out that the correlation between ants and setting on self-sterile trees is probably an anomaly, since ants are unlikely to cause cross-pollination; this also casts doubt on the significance of the correlation obtained by the same method between thrips and setting. It should be noted here that Cope's method of collecting flowers with forceps and plunging them into alcohol would trap few of the Ceratopogonids which may have been in the flowers.

Voelcker (10) proved that at least 25 per cent. of the setting on self-fertile trees at Ibadan, Nigeria, is the result of cross-pollination, probably between neighbouring trees. This is at variance with Cope's (3) conclusion that in Trinidad self-sterile trees are not dependent on their immediate neighbours for fertile pollen. Posnette (6) found two species of *Crematogaster* ants pollinating cacao on the Gold Coast but also showed flying insects to be responsible for at least half the setting on the experimental trees. These flying insects (now known to be *Forcipomyia* sp.) were "more efficient than the pollinating ants, but are not present continuously and cause about half the total pollination in spasmodic bursts".

Billes (*loc. cit.*) carried out experiments which proved that wind and rain cause no pollination. He investigated the insects associated with cacao flowers in Trinidad and confirmed earlier findings that sticky bands have little effect on setting. He found that self-sterile trees followed the same trend of setting as self-fertiles, but set only half as many fruits. He concluded that thrips and aphids effected some self-pollination if present in large numbers. It seems doubtful if pollination by aphids is very effective in causing setting, since he states "aphids caused a high percentage of pollination but this was not reflected in a high rate of setting" There appear to be two reasons for this: he took 10 grains of pollen on the pistil as the minimum required to constitute pollination and this is obviously insufficient to cause setting. Even assuming that every pollen tube effects fertilisation, at least 40 grains would be required. Secondly he says that "large flower cushions bearing a succession of flowers for a long period were most favourable to the aphids, whereas flowers scattered over the tree seldom bore any aphids". The former habit is characteristic of self-sterile trees on which aphid pollination, with self pollen, would be ineffective. Thus, although Billes proved that aphids transfer pollen from anther to stigma in the same flower, it is doubtful if this occurs often in self-fertile trees and also, whether, even when it does occur, sufficient pollen is deposited to cause setting.

That thrips cause some self-pollination seems certain, but Billes doubted if they carry sufficient pollen to cause cross-pollination; if they do not their importance in self-pollination must be slight, since all observers have shown that the trends of setting on self-fertile and self-sterile trees are similar. The thrips population shows marked seasonal variation, and when plentiful they should cause a peak in the setting percentage of self-fertile trees only. Billes showed that both the percentage of flowers with thrips and the percentage pollinated increases from the time the flowers open in the morning until noon; but the same rise in percentage pollination during the day is found on the Gold Coast where cacao-flower thrips are not recorded. Cobley (2) confirmed that neither ants, aphids nor thrips are important pollinators, finding no correlation between setting and numbers of ants and aphids.

Both Billes and Cobley assesssed the insect population of flowers by cutting the pedicel and allowing the flower to fall into alcohol; this method trapped a few Ceratopogonids, but not sufficient to account for all setting. Cobley differed from Billes in finding Ceratopogonids in flowers throughout the dry season, and at no time did the self-sterile trees entirely cease setting. Cobley found that fluctuations in the numbers of these midges produced no corresponding changes in the setting of self-sterile trees. This is not surprising in view of the small number of Cerato-

pogonids he was able to collect, and his apparent disregard of another important factor—the supply of fertile pollen. At certain times of the year self-fertile trees cease flowering while self-sterile trees are flowering profusely. Since the latter can be pollinated only by pollen from a self-fertile tree (in Trinitario and Criollo cacao) they will not set fruit even though their flowers are visited by cross-pollinating agents. Another complicating factor is that Cobley was unaware that he was using two distinct types of self-sterile trees (some Amazon types are fertile with any cacao pollen but their own).

Cobley assumed that different insects are responsible for cross and self-pollination. The writer can find no justification in the literature for this assumption. Ingoring the small and problematical amount of effective self-pollination by thrips and aphids, there seems to be no reason to doubt that most of the effective pollination in Trinidad is cross-pollination between flowers, it being left to chance whether the flowers are on the same or different trees. A flower on a self-fertile tree will set with any pollen, whether it comes from another flower on the same tree or on another self-fertile or self-sterile tree, whereas a flower on a self-sterile tree (of Trinitario type) will set only if the pollen comes from a self-fertile tree. This results in much of the pollination by *Forcipomyia* on a self-sterile tree being ineffective, and setting therefore much lower than on a self-fertile tree, although the number of flowers pollinated may be the same. Posnette (5) has shown that sterile pollen will prevent fertilization by fertile pollen applied simultaneously or subsequently, so that sterile pollen may even have a deleterious effect on setting. It has been shown by several workers that the number of flowers set is more dependent on the number of pollinating agents than on the number of flowers. The *percentage* of flowers *pollinated* on a self-sterile will usually be less than on a self-fertile, merely because of the profuse flowering habit of most self-sterile trees. The *number* of flowers *set* will be less because at least half the flowers will be pollinated with sterile pollen, assuming equal numbers of self-fertile and self-sterile flowers. On Trinidad estates there is usually an excess of self-sterile flowers, further reducing the percentage of flowers setting after pollination. It is unnecessary to postulate different self and cross-pollinating insects to account for the greater setting of self-fertile trees. Ceratopogonid midges cross-pollinating flowers at random will account for all known facts.

Nomenclature

The specimens left at the Imperial College by Billes have been compared with *Forcipomyia ingrami* Carter (determined by J. W. S. Macfie) and Dr. A. M. Adamson considers them probably identical. This is much the commonest species of *Forcipomyia* found in cacao flowers. The writer found another species, about half the size, much darker brown, and with quite different antennae, also pollinating cacao flowers and those of *Theobroma bicolor* H.B.K. A possible third species, intermediate in size, has been sent with the others for identification by the Imperial Institute of Entomology.

Behaviour of Forcipomyia

From November 1943 to April 1944 the writer has been investigating the pollination of cacao in Trinidad with the object of assessing the importance of *Forcipomyia* relative to other pollinating agents. The most surprising fact brought to light was the comparatively large number of *Forcipomyia* found in cacao flowers, since all previous investigators have stressed the rarity of the insect. The writer used a different technique.

Flowers were examined carefully, without moving or breathing on them and those containing an insect were enclosed in a specimen tube by slowly bringing the mouth of the tube near the flower and then closing cork and tube simultaneously on the flower with a swift movement. After some skill is obtained the method succeeds in capturing most specimens, but the fly is easily disturbed and usually leaves the flower rapidly. The method of cutting flowers to drop in alcohol was tried, but succeeded only in a few instances when the midge was inside the petal hood and never when it was on the staminodes.

No attempt was made to assess the number of midges relative to the number of flowers; it is doubtful if this can be done with any accuracy since the size of the territory over which individuals work is unknown, though it is known that cross-pollination occurs over a distance of at least fifty yards (Cope 3). In the case of insects moving from flower to flower, often with long flights in between, the number trapped in flowers within reach in a certain time can be only a small proportion of those actually visiting that particular tree. It is of greater importance to discover the number of flowers visited by a single insect each day.

An attempt was made to discover by direct observation how long a midge usually spends in each flower, the objects of its visits and the efficiency of its pollination. The habits of *Forcipomyia* have been noted by Billes. The present writer observed large numbers and their habits seldom varied. Almost invariably the insect alights on one of the staminodes and walks slowly along it, probing with its mouth parts; occasionally it stops and appears to be feeding. The tissues on the inside of the staminodes seem to be attractive and the midge seldom comes outside the staminode ring. Pollen is carried (usually in a dense mass) held by curved bristles on the thorax and is usually deposited in a cluster on the stigma or style, according to the degree to which the staminodes are splayed away from the pistil. If the staminode runs parallel to the style and the midge walks straight down the inside of the former, a smear of pollen is deposited down one side of the style. Occasionally a midge was seen carrying only a little pollen on its thorax, and this resulted in pollen being scattered on the style.

After a time, varying from three to ten minutes the midge walks through the staminodes and enters the petal hood, on the inside of which run two ridges of raised tissue pigmented like the staminodes ; a third ridge starts near the anther. As the midge walks along these ridges (apparently feeding) its thorax becomes pressed against the anthers so that on emerging from the hood, the midge usually carried a mass of pollen. The midge may rest on the outside of the petal hood, often on the ligule, for several minutes before flying away to alight on the staminodes of another flower. This routine always results in cross-pollination between flowers (not necessarily between trees) ; only twice has self-pollination been observed, and on each occasion the midge fell directly out of the petal hood and returned to the staminodes of the same flower ; but this behaviour was unusual and appeared to be due to the insect either falling accidentally or being disturbed.

Some individual *Forcipomyia* behaved normally with flowers in a specimen tube under a binocular microscope. The mouth-parts are of the piercing type and the probing of the staminodes could be seen clearly. Whether the insect feeds on the purple-pigmented parts of the flower or is searching for eggs or larvae of another insect is not known. *Forcipomyia* pays no attention to the other common inhabitants of cacao flowers.

It is uncertain where these midges breed. Ceratopogonids often have aquatic larvae, but some *Forcipomyia* spp. are known to breed in damp soil or decaying organic matter. F. X. Williams (11) has reported *F. ingrami* breeding on a damp bank in Hawaii. Strickland (7) has obtained *Forcipomyia* sp. from surface soil collected from cacao estates in Trinidad.

Efficiency of Forcipomyia

Forcipomyia is the only pollinator known to effect cross-pollination and the only one known to deposit a large quantity of pollen, either in clusters or in a smear down the side of the cacao style. If *Forcipomyia* is the only cross-pollinator then it follows that all sets on self-sterile trees are the result of *Forcipomyia* pollination, and since these flowers must have pollen from a self-fertile flower the latter must also be pollinated by the same insect. This inference was checked by an examination of styles on sets up to 2 cms. long, beyond which size moulds often obscure the pollen. This gives a direct estimate of effective pollination, as opposed to the examination of flowers, which leads to the inclusion of ineffective pollination because the pollen is either insufficient or of the wrong type. The results given in the table show that about 75 per cent. of sets were certainly pollinated by *Forcipomyia* leaving its characteristic ball of pollen. The remaining 25 per cent. of sets might have been pollinated by *Forcipomyia* leaving a smear of pollen or by other insects. Since the percentage is approximately the same for both self-fertile and self-sterile trees, it is a practical certainty that *Forcipomyia* was responsible also for most of the sets on which the ball of pollen was not seen. 24 sets collected at random from trees on Tortuga Estate had all been pollinated with clusters.

Distribution of Pollen on Cherelles

Self-Sterile Type	Pollen		Self-Fertile Type	Pollen	
	Scattered	Cluster		Scattered	Cluster
Nanay ...	1	10	Maranhao	3	12
Ecuador ...	2	14	Surinam ...	1	4
Criollo ...	1	4	Criollo ...	2	13
Trinitario	3	11	Trinitario	6	16
Total ...	7	39	Total ...	12	45

Pollination of Other Theobroma spp.

Pollination of *Th. bicolor* H. B. K. by *Forcipomyia* sp. was observed, and direct proof was obtained when a midge with its ball of pollen was found trapped on the sticky style of this species.

Flowers of *Th. angustifolia* D. C., *Th. grandiflora* Willd., and *Th.* (*Herrania*) *baloense* differ from those of *Th. bicolor* and *cacao* in having petaloid staminodes and noticeable scent, and being more brightly coloured. Examination of styles never revealed any clusters of pollen, although the majority of flowers of *grandiflora* and *baloense* had been pollinated ; only 2 per cent. of *angustifolia* flowers had been pollinated. In all instances, pollen was scattered over the style and stigma. No Cerapotogonids, thrips or aphids were associated with these flowers, and ants were seldom seen inside flowers. Dipterous flies, probably *Phoridae*, were collected from inside *baloense* flowers and are the most likely pollinators.

Different pollinating agents would prevent natural hybridisation between *Th. cacao* and *Th. angustifolia*, *grandiflora* and *baloense*, pollen of which is fertile with some cacao types (Posnette, *Trop. Agric.* in press). It is interesting to note that *Th. bicolor* and *cacao*, which are inter-sterile, are pollinated by the same insect.

Summary

1. The literature on pollination of cacao published since 1937 is reviewed with special reference to the importance of the Ceratopogonid midge, *Forcipomyia* spp. (? *ingrami* Carter, and other species).

2. The behaviour of *Forcipomyia* in cross-pollinating cacao flowers is described.

3. The efficiency of *Forcipomyia* as a pollinator is estimated by an examination of young fruits for characteristic clusters of pollen.

4. It is concluded that *Forcipomyia* is responsible for most of the effective pollination of cacao flowers in Trinidad.

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CONSERVATION OF HUMUS IN TROPICAL SOILS *

BY

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THE part played by humic manures in soil processes and in plant nutrition, both as a source of mineral elements and by improving the physical condition of the soil, is well known. The advantages of properly devised rotational systems of cropping in soil husbandry are also established by both practice and experience. It is therefore reasonable to expect results of great economic importance by a combination of rotational cropping with humic manuring. The permanent manurial small plots at the Institute of Plant Industry, Indore, afforded an opportunity of studying the relative importance of humic manures and crop rotation on the conservation of soil properties. These plots, sixteen in number, have, since 1933, been receiving annual surface dressings of farm compost, farmyard manure and municipal compost, all at ten tons per acre, and have been under a four-year rotational cropping with (i) cotton, (ii) sann (*Crotalaria juncea*), ploughed in and followed by wheat, (iii) ground nut, and (iv) jowar (*Andropogon sorghum*); one set of four plots (including a control unmanured plot) being under a particular crop during a season. The plots treated with the different humic manures, while yielding more or less alike from year to year with all the crops, had frequently given more than double the yields of the untreated plots.

Surface (0-6 in.) and subsoil (6-12 in.) samples were taken from each of these plots during flowering time in October and examined individually in the laboratory. Some of the results obtained are discussed here. Only the average values for corresponding plots are given in Table I, there being no appreciable difference in the results for plots under different crops.

It will be observed that the surface layers of the manured plots contain a lower percentage of clay and fine silt as compared to the untreated plots. This is no doubt due to the greater infiltration on account of openness of soil, in these cases. It is well recognized that cultivation or addition of organic matter increases pore space and decreases volume-weight, and that these are followed by increased infiltration capacity. From the data, however, it is seen that the differences in pore space or volume-weight between the untreated and manured plots are only small. Likewise, the values for moisture-holding capacity are about the same for all the soils, thus suggesting that, with crop rotation, even unmanured plots do not deteriorate in physical properties. It should be remembered that these plots receive a green manure of sann once during every complete rotation of four years and that, besides, another legume is included in the rotation.

The most significant contrast between the unmanured and treated plots, accounting for the difference in their productivity, is revealed, however, from an examination of the values for carbon and nitrogen, which shows that the latter contain much higher percentages of nitrogen and, especially, of carbon. This enrichment of organic matter is also reflected in the higher structural coefficients of these plots.[1]

That the building up of the soil organic matter through humic manures has steadily increased with time can be seen from Table 2, which gives the percentage increases, over untreated plots, in carbon and nitrogen at different periods for all the humic manured plots (averages).

The high values obtained for carbon and nitrogen during July is obviously due to the plots having received the manures during the preceding month.

Exposure of humus-rich soil, sampled in February 1943, for nearly six months, which included the hot summer months of April to June, had resulted only in a loss of 4.2 and 10.1 per cent.

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Table I

Influence of Manuring and Crop Rotation on Soil Properties

Treatment	Depth (in.)	Clay† fine silt (per cent.)*	Pore space (c.c. per 100 c.c.)†	Volume-weight (gm. per 100 c.c.)†	Moisture content of saturated soil (per cent.)†	Co-efficient of structure	Carbon (per cent.)*	Nitrogen (per cent.)*
Farm compost	0-6	45.6	53.7	140	56.8	0.66	0.89	0.151
	6-12	47.1	59.1	142	58.5	0.69	0.72	0.139
Farmyard manure	0-6	46.6	57.0	142	57.2	0.69	0.84	0 140
	6-12	49.8	55.7	140	58.0	0.70	0.70	0.132
Municipal compost	0-6	48.4	55.9	142	57.3	0.68	0.78	0.130
	6-12	47.6	57.0	140	57.2	0.70	0.72	0.129
Untreated control	0-6	50.0	56.4	143	55.5	0.60	0.59	0.118
	6-12	48.6	57.8	145	56.1	0.60	0.60	0.113

* On oven-dry basis. † On air-dry basis.

Table II

Percentage Increase in Carbon and Nitrogen over Unmanured Plots

Period of Sampling	CARBON		NITROGEN	
	Surface soil	Subsoil.	Surface soil	Subsoil
October 1940	42.4	18.3	18.6	17.7
July 1942 ...	64.1	33.3	69.6	43.5
February 1943	50.8	33.9	35.4	19.6

of carbon from the surface and subsoil samples respectively, the corresponding losses from the untreated plots being 7.9 and 5.1 per cent; but during this period there was considerable fixation of atmospheric nitrogen with both soils. Further work is in progress to study the influence of different environmental factors on the carbon and nitrogen status of these soils.

The conservation of carbon and nitrogen through humic manuring is by no means unfamiliar in temperate regions. Thus from a study of the changes in soil composition caused by fertilizer treatments in the Broadbalk manurial plots at Rothamsted, it is recorded that on the farmyard manure treated plot there has been a marked gain in both carbon and nitrogen, especially in the earlier years, the soil now containing more than twice as much organic matter as most of the other plots[2]. Similar results on the increase in nitrogen content of farmyard manure plots cropped continuously with wheat and barley have been observed at Woburn[3]. An improvement in the nitrogen status of soils following the addition of farmyard manure to soil even under tropical conditions has recently been shown by Dhar and Mukerji[4]; according to these authors, the carbonaceous substances from the decomposition of organic manures assist in the fixation and conservation of soil nitrogen[5].

On the other hand, it has been frequently contended that every soil, depending on a number of complex and interlocked factors, mostly climatic, has more or less definite organic matter and nitrogen status and that it is, therefore, scarcely worth while to attempt to maintain the soil nitrogen and organic matter above certain percentages 6-9. The foregoing observations would suggest, however, that by the application of bulky organic manures these constituents can, within limits, be maintained at higher levels and within an expense that may be justifiable in terms of crop rotation. In analysing the results of fifty years of field experiments at the Woburn Experimental Station, Russell and Voelcker have recently come to the conclusion that soil impoverishment under continuous cropping can best be prevented by a combination of farmyard manure with crop rotation[3].

Humic manures are generally slow-acting and have, in consequence, a much higher residual effect as compared with the immediately available commercial fertilizers. With a deep-rooted crop such as cotton, therefore, their application may not be advisable if their full value is to be utilized. But if they are applied to a previous surface-rooted crop in the rotation they will not only benefit that crop but also have their characteristic effect on the deeper soil layers by the time the turn of the cotton crop comes. This fact has been fully borne out by the work at Indore, where (i) successive application of compost has given consistently high yields with cotton over a period of years, and (ii) in rotation experiments, compost application to the previous crop has always benefited the succeeding cotton crop.

Agronomic practice hitherto has largely been directed towards determining what manures should be applied to each particular crop. The experience with the permanent manurial plots, however, suggests that it would be more beneficial to manure with the object solely of building up

the general fertility of the soil, so as to take care of all crops in the rotation and thus conserve the natural resources of the soil and, in some measure, even improve on them.

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CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Characteristics of Cane Juices

In experiments carried out in Hawaii a large number of samples of mixed juices was tested to determine the properties of the juices from different varieties and from different plantations. It was found that soil and mud did not enter into the colloidal material in the juice, but on the contrary usually decreased the amount of colloids. Passing the mixed juice through a 100-mesh screen was found to remove material amounting at times to more than 1 per cent. of the juice. Both acidity and viscosity were increased, and a faster juice filtration rate obtained. Some evidence was observed, indicating that when large amounts of inorganic colloids are present, clarification will not remove colloids, whereas it will eliminate them when the colloidal ash is low. Regarding cane varieties, it was found with H 109, 31-1389 and 32-8560 that other factors outweighed in most cases any effect of variety. Juices from H 109 are characterised by a high pol.; those from 31-1389 tend towards low pol. and purity and high acidity; while 32-8560 had properties which depend on agricultural and harvesting conditions. Sticks of cane which had been carefully scrubbed showed that no amount of such cleaning can ensure a low content of fine suspended and colloidal material in the expressed juice.—(*Int. Sug. Jr.*, Vol. XLV., No. 529, p. 25.)

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Seasonal Absorption of Nitrogen by Citrus

H. D. Chapman, E. R. Parker & D. S. Rayner —*Calif. Citrograph*, 27, 330, 348-9. Three-year records show that nitrate absorption by young bearing orange trees occurred throughout the year but differed greatly in rate at various seasons. The period of least absorption was in Jaunary and February which was also the period of min. soln. temps. The period of greatest absorption and also of max. soln. temps. was in the summer and fall. Nitrate absorption was more closely related to periods of active root growth and water absorption was more closely related to cycles of active top growth or to the physical factors which regulate root and top growth.—(*Chemical Abstracts*, 1943, Vol. 37, No. 3, Feb. 10, p.663)

Vitamin Enrichment of Flour

The delegates who attended the Washington Nutrition Conference in 1941 were aware of the necessity and opportunity to improve the nation's diet and were conscious of the losses in vitamins in the American diet due to wasteful practices in the consumption of milk; the lack of fruits and raw greens in the diet; the increased and excessive consumption of sugar; and the decortication of grains by modern milling methods which reduce the riboflavin content to one-third, the niacin to one-fifth, and the thiamin content to one-seventh of the original values. These essential vitamins which are removed from flour in milling and baking processes can be readily reintroduced. Thus, in consideration of the above views of deficiencies in vitamins and opportunities for improvement of the diet, the enrichment of flour and bread has now become a matter of government regulations.

Today, according to standards made public by the Federal Security Agency the following minimum and maximum levels per pound of enriched flour are set out: thiamin, 2.0 to 2.5 mg.; riboflavin, 1.2 to 1.5 mg.; niacin, 16.0 to 20.0 mg.; iron, 13.0 to 16.5 mg.; calcium, 500 to 625 mg. (optional); and vitamin D, 250 to 1000 U.S.P. units (optional). The proposed bread standards will shortly be issued.

(C. R. Addinall, *Merk & Co., Inc., Rahway, New Jersey; Journ. Chem. Education*, 1944, Vol. 21, No. 1, January, p. 48).

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Fertilizer Requirements of Avocados and Citrus

Preliminary observations indicate that the manuring of avocados with various types of nitrogen has no beneficial effect on fruit, leaves, set of fruit or amount of crop produced. Manured trees bloomed heavily but the blossoms fell off. Avocados appear to produce the best when the trees compete for nitrogen on poor soils. Citrus possesses much higher nitrogen requirements.—(R. W. Hodgson. *Citrus Leaves* 22, No. 11, 6. *Chemical Abstract*, 1943, Vol. XXXVII, No. 4, p. 1003.)